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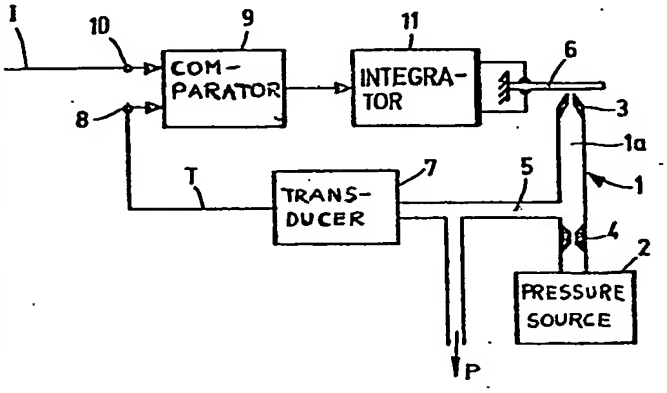
(54) Title: A SIGNAL CONVERTING UNIT INTENDED TO BE INCORPORATED IN A PNEUMATIC CONTROL SYSTEM

(57) Abstract

The unit serves to convert an electrical control signal (I) received at the input of the unit into a pneumatic signal (P). This is emitted at the output of the unit and its value should be proportional to the value of the control signal (I). The unit comprises a tongue-shaped piezoelectric element (6) which is loaded with a voltage dependent on the control signal, so that the element (6) carries out a lateral bending movement which varies with the voltage. The unit also comprises a pneumatic line (1) with a chamber (1a) which is supplied with compressed air via a throttle (4) and from which the compressed air is conducted through a nozzle (3) located near to one side of the piezoelectric element (6) so that the air pressure in the chamber is regulated by the piezoelectric element (6) as a function of the said voltage; and an outlet line (5) leading from the chamber for transmitting the regulated air pressure to the control system as the said pneumatic signal (P). To make the pneumatic signal (P) to the control system accurately follow the electrical control signal (I), a pressure transducer (7) is connected to the outlet line (5), being designed to produce an electrical signal (T) which corresponds to the regulated air pressure, and which is fed back via a feed-back circuit to the input of the unit. Furthermore, the input has a circuit (9, 11) which receives both the electrical control signal (I) and the fed-back electrical signal (T). Th circuit has a device (9) for forming a difference signal by comparing the two signals (I, T) and a device (11) for integrating the difference signal and thereafter producing from the integrated difference signal the voltage with which the piezoelectric element (6) is loaded.



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A Signal Conv rting Unit intended to be incorporated in a Pneumatic Control System

The present invention relates to a signal converting unit intended to be incorporated in a pneumatic control system and used to convert an electrical control signal received at the input of the unit into a pneumatic signal which is emitted at the output of the unit and the value of which should be proportional to the value of the control signal, comprising a tongue-shaped piezoelectric element which is loaded with a voltage dependent on the control signal so that the element carries out a lateral bending movement which varies with the voltage, a pneumatic line with a chamber which is supplied with compressed air via a throttle and from which compressed air is conducted away through a nozzle located near to one side of the piezoelectric element so that the air pressure in the chamber is regulated by the piezoelectric element as a function of the said voltage, and an outlet line leading out of the chamber, for transmitting the regulated air pressure to the control system as the said pneumatic signal.

In Swedish published specification 322.989 (with priority from US 588 057) a signal converter of this kind is described in more detail, comprising a chamber with an inlet aperture and an outlet aperture. A source of fluid pressure by means of which a pressure is obtained in the chamber is connected to the inlet aperture. Near to one of said apertures there is an electrically-actuated piezoelectric tongue. Depending on the strength and the polarity of the control signal, the tongue can be made to move towards or away from the aperture so that the pressure in the chamber is influenced thereby. A fluid pressure value associated with the control signal is derived from this pressure. According to the said published specification, an external force on the tongue is achieved with a

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f ed-back circuit. Th level of the force is associated with the level of the pressure in the chamber and is said to act in the opposite direction to the bending of the tongue occasioned by the control signal. The aim in this case is to restrict the bending of the tongue so that the bending force produced by the control signal is balanced against the fluid pressure. The arrangement therefore works according to the force-balancing principle, i.e. the fluid pressure is dependent on the piezoelectric bending force as a function of the electrical control signal. Accordingly, factors such as the temperature-dependence, non-linearity, and hysteresis of the piezoelectric tongue, as well as the long time instability of the bending forces as a function of the electric control signal, will affect the accuracy of the conversion from an electrical control signal into a fluid pressure value. To the extent that variations occur in the supply pressure from the fluid pressure source, these are not fully compensated, but the compensation process is affected by the said factors.

The temperature-dependence which arises from the piezo crystals of the tongue and difficulties in producing a good adhesion between them entails an error in the order of magnitude of 0.05 - 0.5% per ^{o}C. Hysteresis, which means that, for one and the same control signal value, the tongue carries out dissimilar bending depending on whether the said value is arrived at by increasing or reducing the control signal value, can amount to around 20% and it may take up to 20 hours for the tongue to attain a uniform, stable bending position corresponding to a specific control signal value. Long time stability is also bound up with the mechanical composition of the tongue. Those errors which occur as a result of a lack of long time stability is hard to separate from those which are caused by hysteresis.

In the processing industry in particular there is a need for arrangements which make it possible to carry out conversion of the above-mentioned type with a high degree

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of accuracy, but with the arrangements known up to the pres nt time it has been possible only to reduce the effect of the said factors and therefore an adequately high level of accuracy has not been achieved.

The aim of the present invention is to provide a signal converter of the kind described in the introduction, with which it is possible to convert an electrical control signal into a corresponding pneumatic pressure value with a high degree of accuracy, and which does not have the above-mentioned disadvantages, and this is achieved in that the signal converter has the characteristics which are given in the attached Patent Claim.

The invention will be explained in more detail in the following with reference to the attached Drawing, on which Figure 1 shows schematically and partially as a block diagram a signal converting unit according to the invention for converting an electrical control signal into a corresponding pneumatic pressure value, that is, a so-called I/P converter. Figure 2 shows in block diagram form an alternative embodiment of a signal converter according to the invention.

On the Drawing, 1 is a line connected to a pneumatic pressure source 2, which opens out in a nozzle 3. Between the pressure source 2 and the nozzle 3 in the said arrangement there is a throttle 4 and a pneumatic pressure outlet 5. By means of the pressure source, a pneumatic pressure is produced in a chamber 1a between the nozzle 3 and the throttle 4 in the line 1. Near to the nozzle 3 a piezoelectric element 6 is arranged; this is sensitive to the effect of electrical signals, and has its end furthest from the nozzle firmly clamped in. The side of the element 6 which is nearest the nozzle 3 is formed in such a way that there is a gap between the element and the nozzle through which the air can flow out. Under the effect of the electrical signals, the element 6 can be made to move towards or away from the nozzle 3, depending on the

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strength and polarity of the signal, so that the gap between the element and the nozzle is thereby reduced or increased. The out-flow of air through the nozzle 3 can be influenced in this way, and with it the pneumatic pressure in the chamber 1a and at the pressure outlet 5 is also regulated. This pressure, which can be used as a control pressure for a pneumatic amplifier or a cylinder-piston assembly, has been indicated on the Drawing by P . If no other measures are taken, then, as explained in the introduction, the accuracy is affected negatively by a number of factors when controlling the pneumatic pressure in this way.

As can be seen in Figure 1, according to the invention, a pressure transducer 7 is connected to the pressure outlet 5 for monitoring the pneumatic pressure in the line. The pressure transducer 7 is designed to produce an electrical signal T which corresponds to the said control pressure. The signal T is supplied to one signal input 8 of a comparator 9, the other input 10 of which is supplied with the electrical control signal, called I in the following, which it is desired to convert to a pneumatic pressure value. The comparator 9 is designed to compare the signals T and I and to produce a difference signal corresponding to the difference between the said signals. This is supplied to an integrator 11, the output signal of which is a voltage and acts on the piezoelectric element 6. The integrator 11 is preferably an integrating amplifier and its output signal corresponds to the time integral of the difference signal supplied to the integrator. This means that even small difference signals of a certain duration give rise to output signals from the integrator 11 of the same order of magnitude as larger, but shorter, difference signals.

The arrangement shown in Figure 1 works as an I/P converter and operates in a closed control loop in the following way:

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Depending on the siz and polarity of the difference signals, the element 6 moves as described abov , either away from or towards the nozzle 3, whereby the gap between the element and the nozzle is increased or reduced so that the pneumatic pressure in the chamber 1a, and with it also both the pneumatic pressure value P and the signal T , is varied. Obviously, it is possible to endow the control circuit with characteristics such that the pneumatic pressure value P corresponds very accurately with the signal I . The characteristics of the piezoelectric element 6 or variations in the supply pressure from the pressure source 2 do not affect the accuracy of the converter, which is affected only by the accuracy of the pressure transducer 7.

The comparator 9 and the integrator 11 correspond in their function to a proportional integrating regulator, or so-called P/I regulator. In Figure 2, 12 is such a P/I regulator. The said Figure shows an alternative embodiment of an I/P converter according to the invention, with a fluid amplifier 13 connected to the pressure outlet 5. The amplifier 13 is supplied with pressure from the pressure source 2 via a line 14, and has the task of producing an amplified flow of air and/or an increased pressure value in the outlet line 5 for applications where the flow of air via the throttle 4 is not adequate. The pressure transducer 7 is connected to the output 15 of the amplifier which also forms the output of the I/P converter, i.e. the pneumatic pressure corresponding to the signal I is taken as a working pressure at the output 15. The working pressure may be used, for instance, for controlling the state of a cylinder-piston assembly which is not shown on the Drawing.

Obviously, the signal converter according to the invention may be modified in many ways within the scope of the invention. For example, the piezo-

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electric element 6 may b arranged so that it moves in only one direction, i.e. either away from or towards the nozzle 3, under the effect of the control signal.

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Patent Claim

A signal converting unit intended to be incorporated in a pneumatic control system and used to convert an electrical control signal (I) received at the input of the unit into a pneumatic signal (P) which is emitted at the output of the unit and the value of which should be proportional to the value of the regulating signal, comprising a tongue-shaped piezoelectric element (6) which is loaded with a voltage which depends on the control signal (I) so that the element (6) carries out a lateral bending movement which varies with the voltage, a pneumatic line (1) with a chamber (1a) which is supplied with compressed air via a throttle (4) and from which the compressed air is conducted through a nozzle (3) located near to one side of the piezoelectric element (6), so that the air pressure in the chamber (1a) is regulated by the piezoelectric element (6) as a function of the said voltage, and an outlet line (5) leading from the chamber (1a) for transmitting to the control system the regulated air pressure as the said pneumatic signal (P), characterised in that a pressure transducer (7) designed to produce an electrical signal (T) corresponding to the regulated air pressure is connected to the outlet line (5), and is connected back via a feed-back circuit to the input of the unit, and that the input has a circuit (9, 11; 12) which receives both the electrical control signal (I) and the fed-back electrical signal, and which has a device (9) for forming a difference signal by comparing the two signals, and a device (11) for integrating the difference signal and thereafter producing from the integrated difference signal the voltage with which the piezoelectric element (6) is loaded, the pneumatic signal (P) to the control system accurately following the electrical control signal (I).

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FIG 1

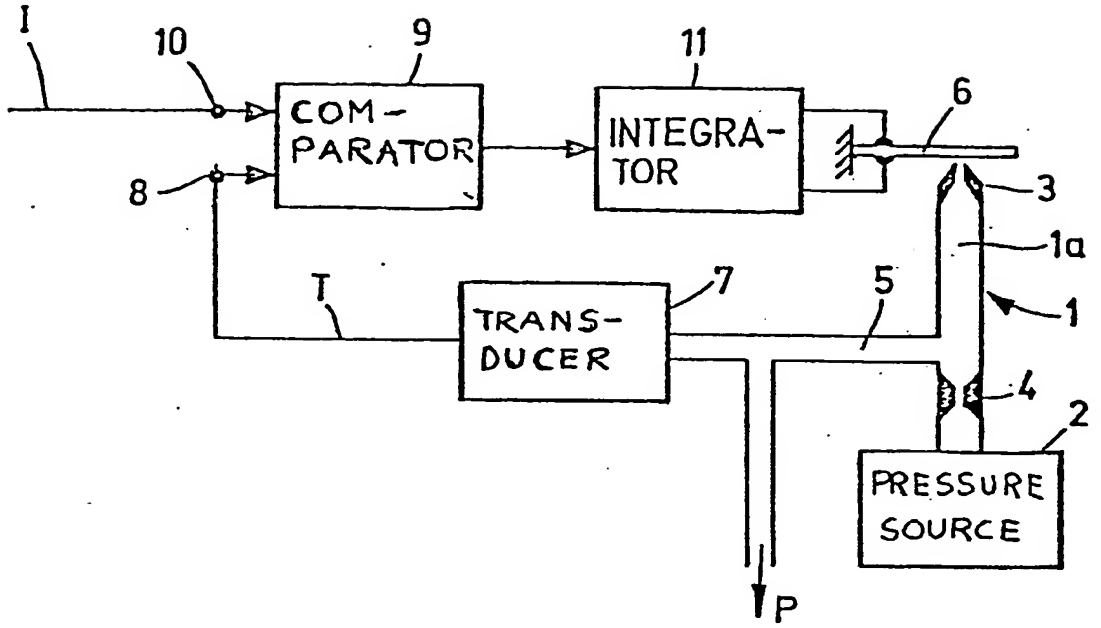
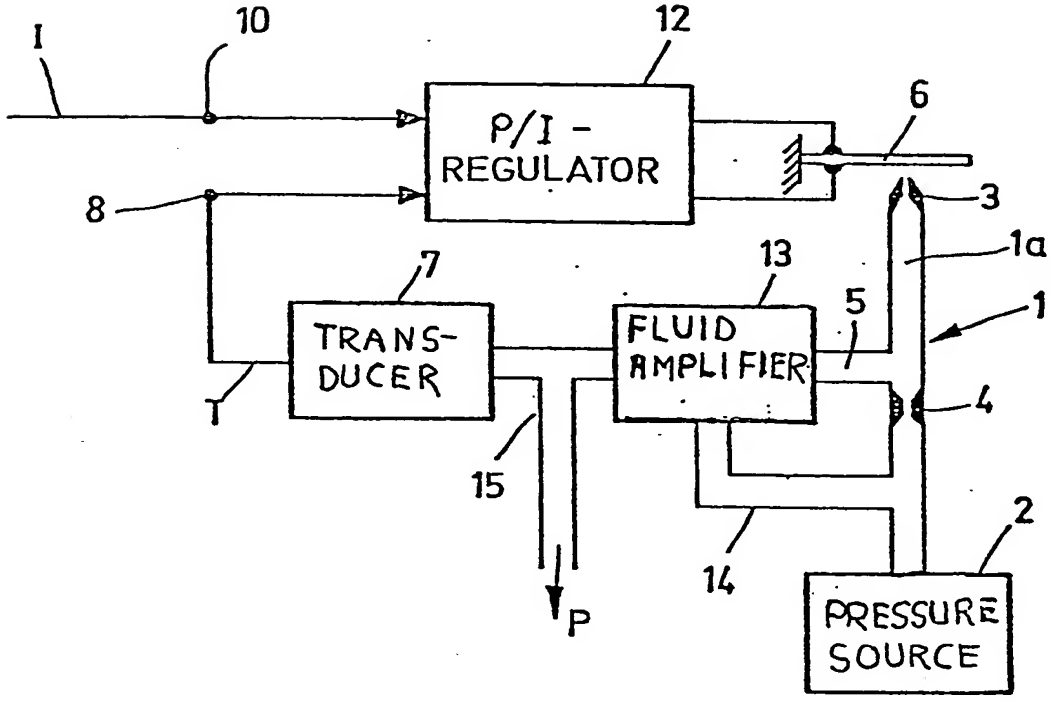


FIG 2



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INTERNATIONAL SEARCH REPORT

International Application No PCT/SE80/00057

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC 3

F 15 B 5/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	F 15 B 15/00, 9/06, 07, 13/12, 16, 21/00, 08; G 05 D 16/18, 20
US CL	91/361, 363; 137/82-86

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [5]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [15] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	SE, B, 322 989 published 1970, April 20, Fisher Governor Company	1
X	FR, A, 1 183 778 published 1959, July 13, Compagnie Francaise, Thomson-Houston	1
A	US, A, 4 061 155 published 1977, December 6, Sopha	1

* Special categories of cited documents: [16]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [1]	Date of Mailing of this International Search Report [2]
1980-05-13	1980-05-23
International Searching Authority [1]	**Signature of Authorized Officer** [20]
Swedish Patent Office	Per Cederholm